OBSERVATIONS ON THE REPRODUCTION AND EMBRYOLOGY OF THE LAHONTAN TUI CHUB, *GILA BICOLOR*, IN WALKER LAKE, NEVADA

James J. Cooper[1]

Abstract.— Various aspects of the reproduction and embryology of Walker Lake Lahontan tui chub, *Gila bicolor*, were investigated during the spring-summer period of 1976, 1977, and 1981. Tui chub were found to spawn in littoral regions of the lake beginning in late May or early June. Early in the season male chub substantially outnumbered females over the spawning grounds, with a normal 1:1 sex ratio gradually approached as the season progressed. The developmental period between fertilization to hatch-out was shortened by increases in water temperature. Selected stages of embryonic development are described from egg fertilization through post-hatch.

The Lahontan tui chub, *Gila bicolor*, is a cyprinid found in the Columbia, Klamath, and Sacramento river systems as well as in a number of isolated interior basins of California, Oregon, and Nevada (Bailey and Uyeno 1964, Moyle 1976). The Walker, Carson, Truckee, and Humboldt river system of the Lahontan Basin all support populations of tui chub (La Rivers 1962), as well as numerous isolated springs in the north central Great Basin (Hubbs et al. 1974).

Little information exists concerning the reproductive behavior and embryology of the tui chub, especially in the Lahontan system, where they are an integral trophic link in the food chain and heavily preyed upon by various piscivorous fishes. Kucera (1978) reported on the reproductive biology of the tui chub from Pyramid Lake, Nevada. Kimsey (1954) described some early life history information of the tui chub from Eagle Lake, California. Harry (1951), working on the same project produced one of the first papers on tui chub embryology. Spawning and general reproductive behavior of tui chub in East and Paulina lakes, Oregon, was described by Bird (1975). Other less quantitative literature on the subject includes observations on Pyramid Lake, Nevada (Snyder 1918, La Rivers 1962).

Study Area

Walker Lake, the second largest natural body of water entirely within the state is located in west central Nevada approximately 209 km southeast of Reno and 10 km north of Hawthorne. The lake is a remnant of pluvial Lake Lahontan, which once occupied west central and northwestern Nevada as well as the Honey Lake region of northeastern California (La Rivers 1962). Walker Lake is a terminal, alkaline-saline lake with a total dissolved solids content of over 12,500 mg/l, of which sodium chloride, sulfates, and bicarbonates make up approximately 97 percent of the total ionic content (Koch et al. 1979).

Walker Lake has a surface area of 15,000 ha and a maximum length of 25 km and maximum width of 9 km. The maximum depth of the lake is near 33 m and the mean depth is 20 m. The elevation of Walker Lake has been declining very rapidly in recent geological time, with subsequent increases in salinity and alkalinity. Since 1915 the level of the lake has dropped at an average rate of 0.58 m per year (Koch et al. 1979). Upstream agricultural diversion of the Walker River, the only tributary entering the lake, has been the primary factor responsible for the increased rate of desiccation since the turn of the century.

Methods

The data presented in this paper were collected during the spring-summer period of 1976, 1977, and 1981. Observations of tui

[1]Bioresources Center, Desert Research Institute, Reno, Nevada 89506.

chub spawning in Walker Lake were accomplished by slowly and quietly approaching shore areas during the spawning season. Spawning chub were easily detected as their fins would break the water surface, their presence many times accompanied by splashing. Sampling techniques included the use of a 15.2 m beach seine, multipaneled gill nets, and hook and line. Notes on behavior and environmental variables such as water temperature, depth of spawning, and substrate type were all recorded concurrently.

The embryological development of the tui chub was observed and monitored through an incubation system that closely simulated lake conditions. Two 6.5 l May-Sloan hatching jars were set up at the Desert Research Institute's mobile laboratory on the shore of Walker Lake. Lake water was pumped to a large holding tank on a hill behind the facility and a line was installed to each jar. Each of the lines was equipped with a valve to control flow volumes through the hatching jars at 0.5–1 l per minute. During the incubation periods temperature was monitored at least every four hours with a thermometer measuring to the nearest 0.5 C.

Spawn was obtained by capturing ripe males and females in gill nets set near shore. At least two females and five males were used to produce the fertilized eggs for each incubation period. Ripe females were spawned by hand into a flat-bottomed plastic bowl immediately after capture. Milt from ripe males was extruded over the eggs and lake water added. After the water was added, the bowl was swirled gently to mix the sperm and eggs. After the initial mixing, the fertilized eggs were allowed to stand for a few minutes and then were thoroughly rinsed with lake water a number of times. Approximately one-half hour after water hardening, the eggs were introduced to the hatching jars.

Developmental sequences were obtained with the use of a compound Tiyoda microscope and a 35 mm Minolta camera with a Vivitar microscope adaptor, using Kodak-Kodacolor ASA 125 film. It was found that micrograph magnification revealed the most detail at 40X. Line drawings were produced from these photographs.

Results and Discussion

Spawning

Tui chub from Walker Lake became sexually mature during the spring of their third year, with the exception of a few males that were observed to be mature at the end of the second year. This age is consistent with what Kimsey (1954) found in Eagle Lake, California, and Kucera (1978) in Pyramid Lake, Nevada.

Male and female tui chub are easily identified to their sex during the spawning season. The most obvious change occurs in the male who become covered with small nuptial tubercles. The females undergo a slight enlargement of the anal region and exhibit a marked protrusion of the genital papilla. In both sexes the fins take on a slight reddish coloration.

Spawning activity was first observed on 8 June and 20 May in 1976 and 1977, respectively, at Walker Lake. The surface water temperature on 8 June was 16.5 C and on 20 May was 13.5 C. Kimsey (1954) found spawning to first occur in Eagle Lake near a temperature of 15.5 C.

Spawning observations revealed large schools of chub within 1–2 m of the shoreline at a depth of from .25 to 1 m. The dorsal and caudal fins of the fish broke the surface of the water in many instances. Substrate type varied from small pebbles to large rocks with small amounts of algae attached to their surface in many cases. Actual spawning was not observed, but an examination of a spawning site revealed a number of chub eggs between the rocks and attached to algae.

Available literature is consistent in stating that tui chub are inshore spawners. In Eagle Lake, California, mature tui chub were found to migrate from the deeper southern end of the lake to the shallower northern end during the spawning season (Kimsey 1954). La Rivers (1962) also made the observation that tui chub congregate in shallow shoreline areas to spawn. Gill net catches at Pyramid Lake revealed that 97 percent of the adult benthic tui chub population was inshore in July (Vigg 1978).

Sex ratios were calculated from a sample of 852 fish collected over a 15 month period.

The ratio of males to females was 1:1.16, which does not deviate substantially from an assumed 1:1 ratio. Pyramid Lake female tui chub were found to survive to an older age than males (Kucera 1978), which may explain the sex ratio favoring females in Walker Lake.

Nevertheless, this ratio deviates dramatically during the spawning season. On 29 May 1981, 103 tui chub were captured by seining schools over their spawning ground. Males outnumbered females 84 to 19, which is a sex ratio or 4.4:1. From this group, age III fish were represented by 81.5 percent of the individuals, with the remainder ages II, IV, and V.

Gill netting from June through July 1976 at inshore locations also revealed males entering spawning grounds earlier than females (Fig. 1). On 15 June males comprised 85.1 percent of the population but decreased to 54.3 percent by 19 July. Kucera (1978) found similar results in Pyramid Lake, where from May to June males increased from 49 to 62 percent.

Also of significance are the apparent sexual differences in readiness to spawn at various times in the season. Early in the spawning season (late May) all the males were "running ripe" with sperm, whereas none of the females would extrude their eggs following gentle pressure to the abdominal region. The peak in spawning activity was estimated to occur in mid-July, when the sex ratio again approached normality and a majority of the females in the catches were in a ripe condition. Ripe female chub were difficult to find in gill net sets in late July and early August, although all the males would continue to discharge sperm with gentle handling. From a

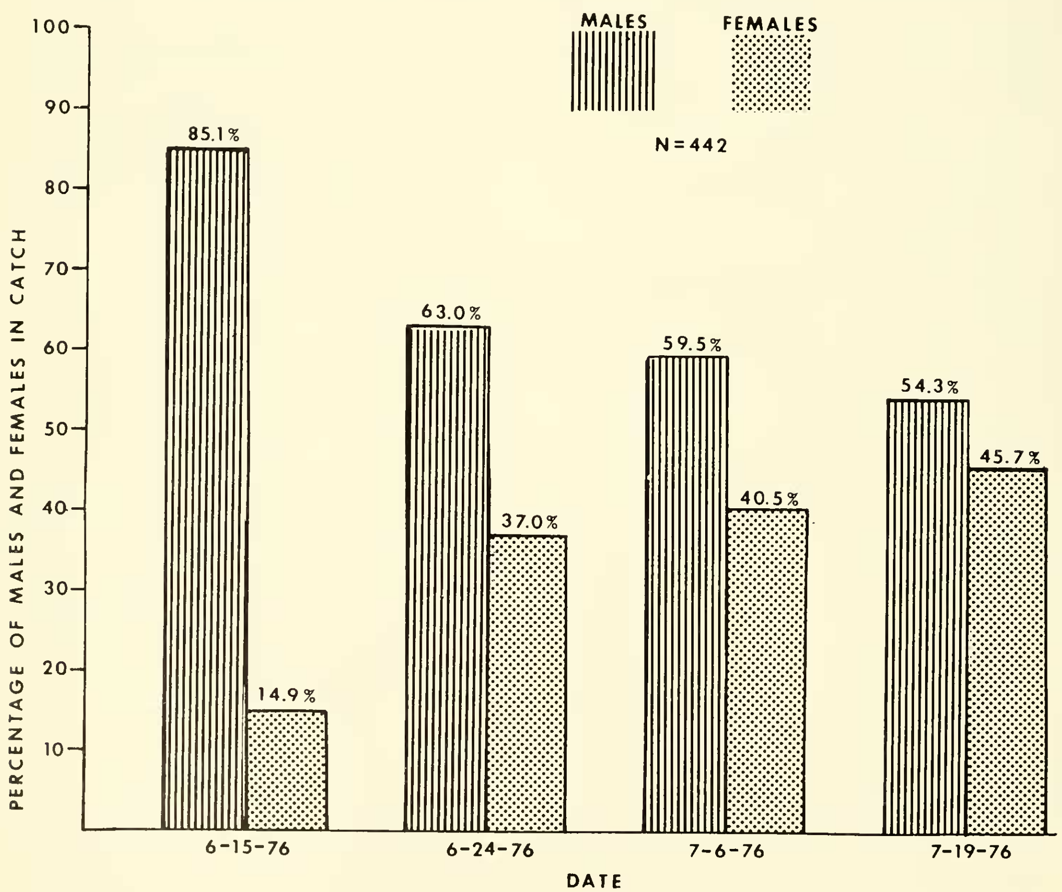

Fig. 1. Percentage of male to female Lahontan tui chub caught in bottom set gill nets in from 5 to 7 m of water between 15 June and 19 July 1976 in Walker Lake, Nevada.

total of 174 females collected from an inshore gill net set, only 3 individuals (1.7 percent) were in a running ripe condition on 4 August. Upon examination of apparently spent females, it was found that they still contained eggs, a fact that suggests multiple and protracted spawning.

It appears as though males are the first to become sexually active in the spring and the last to become inactive at the termination of the spawning season. Reproductive behavior such as this would seem to ensure many spawning males for each female and in turn a greater chance of egg fertilization.

Embryonic Development

Observations on the embryological development and early larval stages of the tui chub were conducted from mid-July to early August 1976 on Walker Lake. The rate of development was found to be dependent upon water temperatures (Fig. 2). An increase in temperature from 18.8 to 24.4 C accelerated embryo development by approximately 85 percent.

Harry (1951) incubated tui chub eggs from Eagle Lake, California, at 7.2 C for the first 100 hours and then allowed temperatures to vary from 1.1 to 28.9 C. At this variable temperature regime the eggs hatched out on the 12th day of incubation. Kimsey (1954) also incubated Eagle Lake tui chub eggs in a quart jar, where the air temperature fluctuated from 4.4 to 32.2 C, and found the fry actively feeding in 9 days. In East Lake, Oregon, Bird (1975) hatched out tui chub eggs in 192 and 142 hours at 14.6 and 21.9 C, respectively. He concluded that highly fluctuating incubation temperatures retarded the developmental period in comparison to stable temperature regimes.

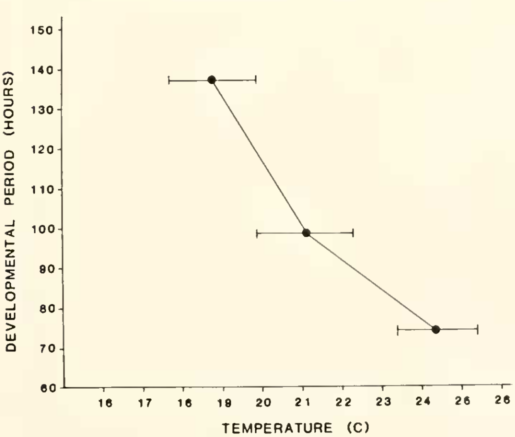

Fig. 2. Developmental period for Lahontan tui chub eggs incubated at three mean water temperatures, July and August 1976, Walker Lake, Nevada. Bar equals two standard deviations.

The ability of tui chub eggs to tolerate wide variations in water temperatures is a valuable survival trait for the species. The eggs incubate in water that is shallow enough to warm up during periods of high solar radiation and cool down at night. The short duration of the egg stage is also a highly beneficial adaptation because environmental conditions have a shorter period of time to cause mortality at this critical stage of development.

Lahontan tui chub eggs flow freely from females when they are in a condition to accept fertilization. It was found that when eggs were forcibly extruded fertilization would not occur. Freshly stripped eggs are approximately 1–1.5 mm in diameter, yellowish, opaque, and very adhesive. They are demersal and their specific gravity is considerably more than that of Walker Lake water because the eggs quickly sink to the bottom. After successful fertilization, the perivitelline space becomes separated from the zygote and swelling occurs, giving the egg as a whole an outer diameter of 1.5–1.8 mm.

Stages of embryonic development were monitored continuously from fertilization through hatch-out (Fig. 3). At 21.1 C, by 6 hours the blastodermal cap had formed at the animal pole and covered about one-fourth of the circumference of the yolk. Midgastrulation had occurred by 10 hours and late gastrulation by 12.5 hours, with the embryo becoming recognizable around the yolk. After 22.5 hours of incubation, the embryo length was approximately two-thirds of the way around the yolk circumference, with the head region discernible from the tail. At 31 hours the embryo had 6–8 somites, the optic vesicles were easily discernible, and the yolk sac was still very large. The embryo began to squirm within the egg case at 44.5 hours and the notochord was visible. At this stage the heart, as well as blood flowing throughout the circulatory system, could be seen. Just prior to hatching at 96 hours, the embryo had surrounded the egg yolk and completely filled the chorion. At this stage the eyes had become pigmented, and the embryo moved almost constantly. Just after hatching, the larva body is curved with slight pigmentation, the swim bladder is visible, and they tend to swim periodically. Afterwards they quickly sink to the bottom. This is consistent with what Bird (1975) found in East and Paulina lakes, Oregon, although Harry (1951) found larvae exceptionally active and able to swim rapidly just following hatching.

By 166 hours after fertilization (70 hours after hatching), the larvae were 8–10 mm long and the pectoral fins had begun to form. Four gill chambers and arches were easily discernible posterior to the eyes, and melanophores covered more than half of the body. Swimming action had increased but had not yet become consistent. The yolk sac was very small at this stage, but feeding had not yet been observed.

The majority of the larvae had died by 237.5 hours, probably of starvation. Most of the fins were present and the body and head were heavily covered with melanophores. Myomeres were well developed and the larva was able to hold itself in a swimming, midwater position. It is presumed that the fish must soon begin to feed at this stage of development because the yolk sac had been completely absorbed.

LITERATURE CITED

BAILEY, R. M., AND T. UYENO. 1964. Nomenclature of the tui chub, cyprinid fishes from western United States. Copeia 1964(1): 238–239.

BIRD, F. H. 1975. Biology of the blue and tui chubs in East and Paulina lakes, Oregon. Unpublished thesis. Oregon State Univ., Corvallis. 165 pp.

HARRY, R. R. 1951. The embryonic and early larval stages of the tui chub, *Siphateles bicolor* (Girard), from Eagle Lake, California. California Fish and Game 37(2):129–132.

HUBBS, C. L., R. R. MILLER, AND L. C. HUBBS. 1974. Hydrographic history and relict fishes of the north central Great Basin. Mem. California Acad. Sci. 7:259.

KIMSEY, J. B. 1954. The life history of the tui chub, *Siphateles bicolor* (Girard), from Eagle Lake, California. California Fish and Game 40(4):395–410.

KOCH, D. L., J. J. COOPER, E. L. LIDER, R. L. JACOBSON, AND R. J. SPENCER. 1979. Investigations of Walker Lake, Nevada: dynamic ecological relationships. Desert Res. Inst., Bioresources Cent. Pub. No. 50010. 191 pp.

KUCERA, P. A. 1978. Reproductive biology of the tui chub, *Gila bicolor* in Pyramid Lake, Nevada. Great Basin Nat. 38(2):203–207.

LA RIVERS, I. 1962. Fishes and fisheries of Nevada. Nevada Fish and Game Comm. 782 pp.

MOYLE, P. B. 1976. Inland fishes of California. Univ. of California Press, Berkeley. 405 pp.

SNYDER, J. O. 1918. The fishes of the Lahontan system of Nevada and northeastern California. Bull. U.S. Bur. Fish. 35:31–86.

VIGG, S. 1978. Fish ecology. Chapter 8 in W. F. Sigler and J. L. Kennedy, eds. Pyramid Lake Nevada, ecological study final report. W. F. Sigler and Associates, Inc. Reno, Nevada.

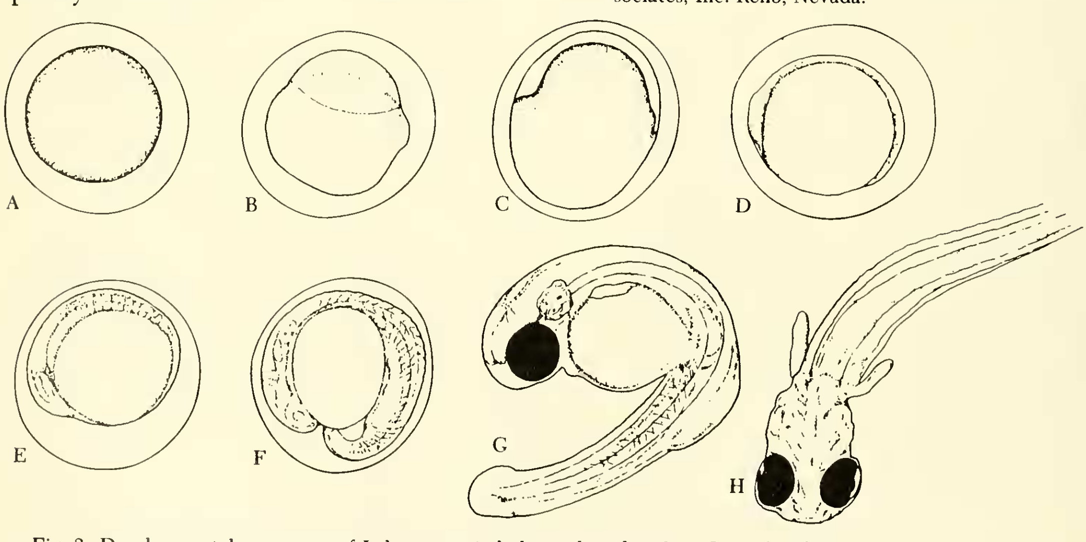

Fig. 3. Developmental sequences of Lahontan tui chub incubated at 21.1 C. A, One hour after fertilization; B, 6 hours; C, 12.5 hours; D, 22.5 hours; E, 31 hours; F, 44.5 hours; G, 96 hours, just after hatching; H, larva 70 hours after hatching.